Reproducibility of two functional field exercise tests for children with cerebral palsy who self-propel a manual wheelchair

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ABBREVIATIONS

1SPT	One-stroke push test
6MPT	6-minute push test
6MWT	6-minute walk test
HR_{6MPT}	Heart rate recorded after the 6MPT
SDD	Smallest detectable difference

AIM The aim of this study was to examine the test–retest reproducibility (reliability and agreement) of the 6-minute push test (6MPT) and the one-stroke push test (1SPT), and construct validity of the 6MPT in children with cerebral palsy (CP) who self-propel a manual wheelchair.
METHOD Seventy-three children and adolescents with spastic CP (51 males, 22 females; mean age 11y 9mo, SD 3y 7mo, range 4–18y; three unilateral, 70 bilateral) using a manual wheelchair for at least part of the day were recruited from and tested in different rehabilitation settings in the Netherlands and Brazil. Participants were classified as Gross Motor Function Classification System (GMFCS) level II (n=7), III (n=36), or IV (n=30).
RESULTS Intraclass correlation coefficients (ICCs) for distance covered on the 6MPT (mean distance 266.5m, SD 120.6m) and the 1SPT (mean distance 4.5m, SD 2.7m) showed excellent reliability (ICC=0.97) for both tests. There was a significant correlation between the 6MPT and the 1SPT (r=0.73; p<0.001), and between the 6MPT and heart rate during the 6MPT (r=0.29, p=0.014).
INTERPRETATION These results indicate that both the 6MPT and the 1SPT test are reproducible functional tests for young people with CP who self-propel a wheelchair. Agreement for the 6MPT seems relatively large for children who perform short distances. Construct validity is supported for the 6MPT in children with CP.

Cerebral palsy (CP) is a complex condition and its impact on individuals varies widely. This variation is represented in the Gross Motor Function Classification System (GMFCS).[1,2] Observations showed that children with CP use a range of mobility methods across settings, particularly those categorized in GMFCS levels II to IV.[3,4] For example, a child who walks independently at home may use crutches at school and a wheelchair in the community.

Children and adolescents with spastic CP often have poor physical fitness[5] as has been well documented by means of exercise tests. Moreover, exercise testing has been used as a primary outcome measure of therapy and exercise programmes in children and adolescents with CP.[6] However, in the case of children and adolescents with CP who rely, for short or longer distances, on a manually propelled wheelchair for locomotion, there is a shortage of exercise tests to examine exercise capacity.[7]

Laboratory tests are usually used to evaluate maximal cardiorespiratory responses during an incremental arm cranking exercise. However, this kind of testing requires many resources in terms of qualified personnel and sophisticated instrumentation. Both are not always available in a clinical setting. Moreover, the role of such testing is limited in children and adolescents who self-propel a wheelchair, as maximal performance may be limited by spasticity, muscle strength, or skills, rather than exertion. For this reason, submaximal exercise tests have been suggested as an alternative to maximal exercise testing.[7]

The 6-minute walk test (6MWT) is the most widely used submaximal exercise test for measuring functional exercise capacity in the ambulatory population.[8] Currently, the 6MWT is regarded as the most suitable method for assessing submaximal levels of functional exercise capacity in children and adolescents with CP. However, a similar test is, however, lacking for persons with CP who self-propel a wheelchair. A 6-minute push test (6MPT), which we have adapted from the 6MWT, may be a suitable alternative for this population. However, no information about the clinimetric properties of the 6MPT[7] has yet been published.

When self-propelling a wheelchair during an exercise test or in daily life, the propulsion technique is important and highly dependent on the functional ability of the user and is related to various physical attributes. In children with CP these physical attributes (e.g. muscle strength, balance, muscle tone and spasm, range of motion) may vary and influence propelling skills. To date, there is no easy-to-use test to evaluate the propulsion skill of children with CP who self-propel a wheelchair. The one-stroke push test (1SPT), developed by May et al.[9] has been shown to be reliable in a group of adult males with spinal cord injury, and it seems it may be of interest for use in children and adolescents with CP. Moreover, it seems to be an appropriate test to gain insight into propelling skills and related physical factors.

The 1SPT would also seem to be an appropriate functional field test for children with CP who self-propel a manual wheelchair. However, again the clinimetric properties of this test in children with CP are unknown.

In the present study we investigated the test–retest reproducibility of the 6MPT and 1SPT in children with CP who self-propel a manual wheelchair. A secondary aim of this study was to examine construct validity of the 6MPT. We hypothesized a strong and significant correlation between 6MPT distance and 1SPT distance, as well as a strong and significant correlation between 6MPT distance and the heart rate at the end of the 6MPT.

METHOD

This study focused on children with CP who were classified in GMFCS levels II, III, and IV and who self-propelled a wheelchair for at least a part of the day. To be included, participants had to be within the age range 4 to 18 years, diagnosed with spastic CP, and classified as level II, III, or IV on the GMFCS, Expanded and Revised Version. Cognitively, the study participants had to be capable of following simple instructions. A convenience sample of 73 children with CP (51 males, 22 females) and their parents agreed to participate and provided written informed consent. The COnsensus-based Standards for the selection of health Measurement Instruments (COSMIN) checklist[10] recommends that at least 50 participants be included in a reliability study, suggesting that this study was sufficiently powered.

All participants were receiving rehabilitation services in the Netherlands (*n*=62) or Brazil (*n*=11) at the time of the study. Group characteristics are described in Table I. The study was approved by the institutional review board of the University Medical Center Utrecht and the SARAH Network Ethics Committee, Brazil. Before testing, weight and height were measured using electronic scales (Seca, Hamburg, Germany; Soehnle, Nassau/Lahn, Germany; Stimag, Hoofddorp, the Netherlands) and stadiometer (Shorr Productions, Maryland, USA; Seca, Hamburg Germany) respectively. Body mass index was calculated as body mass/height^2 (kg/m^2).

What this paper adds

- The 6MPT and the 1SPT are reliable and valid submaximal exercise tests for children with CP who self-propel a wheelchair.
- The limits of agreement for the 6MPT seem relatively large for distances under 200m.

Procedures

For all testing, the participants used their own wheelchair and back support. During the test period, no adjustment was made to the wheelchair configuration. To evaluate test–retest reliability, two repeat trials were used. Participants were not informed about the test results during the study. Both tests were performed within a period of 2 weeks in 10 rehabilitation centres in the Netherlands and one in Brazil. The therapists were given written instructions on the application and scoring of both tests. The same observer (there were 38 observers in total) administered both tests in the same child.

Measures

6-minute push test

The 6MPT, developed by the authors, is a self-paced test that measures the distance the participant can propel quickly on a flat, hard surface within a period of 6 minutes. A course of 10m was used, because this is a length that can be replicated indoors in most practices. Marking tape was placed at 2m intervals along the course.

The participants were instructed to restrain from vigorous exercise for 2 hours before testing. A 'warm-up' period before the test was not allowed. Before the test, participants rested in their chair for 5 minutes near the starting position and were then moved to the starting line. The participants were instructed as follows: 'The object of this test is to propel as far as possible for 6 minutes by propelling back and forth on this 10-metre course defined by these markers/taped lines. Six minutes is a long time, so you will be exerting yourself. You will probably become out of breath or exhausted. You may slow down, stop, and rest as necessary, but resume propelling as soon as you are able. You will be propelling back and forth around the markers here. You should pivot briskly around the markers and continue back the other way without hesitation. Are you ready to do that? Remember that the objective is to

Table I: Participants characteristics

	GMFCS level II (*n*=7)			GMFCS level III (*n*=36)			GMFCS level IV (*n*=30)		
Variable	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age, y	9.9	4.7	6.2–16.5	12.0	3.8	4.7–18.3	12.2	3.4	7.6–18.7
Height, cm	136.9	20.5	118.0–164.0	145.4	21.7	102.0–182.0	142.8	22.8	106.0–195.0
Body mass, kg	35.3	18.1	18.8–67.6	45.7	19.0	15.0–88.5	41.9	17.5	17.1–104.2
BMI, kg/m^2	17.7	4.0	13.1–25.1	20.8	5.5	13.6–34.7	20.0	4.6	12.2–28.0

GMFCS, Gross Motor Function Classification System; BMI, body mass index.

ride as far as possible in 6 minutes, but do not start speeding. I will keep track of the number of laps you complete. Start now, or whenever you are ready.'

During the test, standardized instructions according to the American Thoracic Society[11] guidelines were used. The assessor, standing near the starting line throughout the test, recorded each lap as it was completed (=20m). Performance of the 6MPT was supervised by an investigator, who sounded an electronic timer 6 minutes after the test started. At the end of the 6-minute period, the total distance (to the nearest metre) travelled was recorded. The heart rate (HR_{6MPT}), recorded with a heart rate monitor, was read directly at the end of the 6MPT and documented on a data sheet.

One-stroke push test

For this test, adapted from May et al.,[9] participants used their own wheelchair. At the start of the test, the two front wheels of the wheelchair were positioned on the starting line (marked using two cones and a line on the floor). The participant was instructed as follows: 'You must try to cover as much distance as possible by using just one push (using both hands if possible). At the start your front wheels have to be at the starting line. After your push you have to let your wheelchair roll, until it stops. I will measure the distance you have covered and record it on the score-sheet. We will do this test three times.'

Participants propelled the wheelchair forward by pushing once with maximal effort. They were free to choose where to place their hands to begin propulsion. Once the wheelchair stopped, the most anterior point of the front wheels was marked to indicate the distance covered. If the push was not symmetrical, the position of the most anterior front wheel was marked. The distance (cm) between the marked points and the starting line was recorded. This test was performed three times, and the mean 1SPT distance was calculated. The 6MPT and 1SPT were separated by a minimum of 2 days and a maximum of 16 days (mean 4.3d; SD 1.4d).

Data analysis

Reproducibility

Reproducibility comprises both reliability and agreement.[12] Reliability was measured by intraclass correlation coefficients (ICC, two-way mixed). An ICC greater than 0.80 reflects excellent reliability, whereas ICCs from 0.70 to 0.79 reflect good reliability.[13] The recommended minimum for the lower limit of the 95% confidence interval (CI) is 0.85.[14] In the case of agreement, the standard error of measurement (SEM) was used to determine the precision of the total score of both tests. The SEM describes the error in interpreting the test score of an individual. It allows for estimation of the 'true' test performance using a reliability coefficient and is computed by multiplying the standard deviation of the total score by the square root of 1 minus its reliability coefficient ($SEM = SD \times \sqrt{1-ICC}$). It is important to know, especially in clinical practice, whether the differences in test–retest on an individual basis are at or over one smallest detectable difference (SDD) level. The SDD of the total score was computed as $1.96 \times \sqrt{2} \times SEM$ to obtain a 95% CI.[12] The reliability for the different GMFCS levels and age groups (7–12y and older) was calculated to examine if the reliability varied between GMFCS levels. The Bland–Altman procedure[15] was used to check for heteroscedasticity of the test and retest of both the 6MPT and 1SPT.

Construct validity

The association between the 6MPT and 1SPT and HR_{6MPT} was tested using the Pearson's correlation coefficient. An alpha-value of less than 0.05 was considered statistically significant.[13]

RESULTS

All participants seemed to comprehend what was expected of them and successfully completed the testing procedures.

Reproducibility

6-minute push test

For distance covered on the 6MPT (mean distance 266.5m; SD 120.6m; range 27.5–580m), the ICC was 0.97, with an SEM of 20.9 and SDD of 57.9 (Table II). The Bland–Altman plots (Figs 1 and 2) revealed no significant learning effect between the first and second test performances. Furthermore, the limits of agreement ranged from −54.8 to 62.2 for distance covered in the 6MPT, indicating that a change within an individual must fall outside of this range to be considered meaningful.

As can be seen in Table III, reliability for all GMFCS levels and age groups is excellent. The lower limit of the 95% CI for the children within GMFCS level II is below the recommended minimum (but only seven children were included in the analysis).

One-stroke push test

For distance covered on the 1SPT (mean distance 4.4m; SD 2.7m; range 0.2–12.9m), the ICC was 0.97, with an SEM of 0.5 and SDD of 1.4 (Table II). The Bland–Altman plot (Fig. 2) revealed no significant learning effect between the first and second test performances. Furthermore, the limits of agreement ranged from −1.6 to 1.7 for distance covered on the 1SPT, indicating that a change within an individual must fall outside of this range to be considered meaningful.

Table II: Test–retest reliability statistics

Test	ICC	95% CI of ICC	SEM	SDD	LOA
6-minute push test	0.97	0.96–0.98	20.9	57.9m	–54.8 to 62.2
One-stroke push test	0.97	0.96–0.98	0.5	1.4m	–1.6 to 1.7

ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; SDD, smallest detectable difference; LOA, limit of agreement.

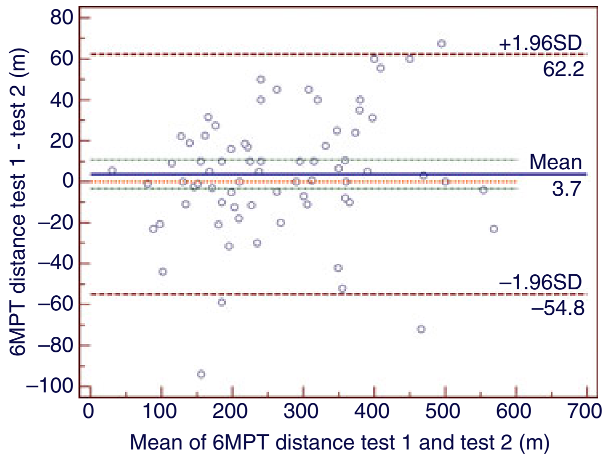

Figure 1: Bland–Altman plot of distance during test and retest on the 6-minute push test (6MPT).

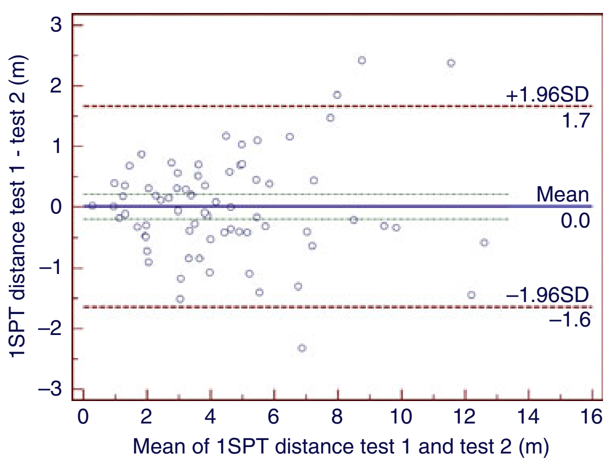

Figure 2: Bland–Altman plot of distance during test and retest on the one-stroke push test (1SPT).

Table III: Test–retest reliability statistics of the 6-minute push test by GMFCS level

	Distance (m) mean (SD)	ICC	95% CI of ICC	SEM	SDD
GMFCS level					
II (*n*=7)	298.6 (92.3)	0.97	0.80–0.99	16.0	44.3
III (*n*=36)	289.5 (121.1)	0.98	0.97–0.99	17.1	47.4
IV (*n*=30)	239.4 (130.0)	0.96	0.91–0.98	26.0	72.1
Age					
7–12y (*n*=40)	239.3 (99.3)	0.98	0.96–0.99	14.0	38.8
13–18y (*n*=33)	306.8 (140.9)	0.97	0.94–0.98	24.4	67.3

GMFCS, Gross Motor Function Classification System; ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; SDD, smallest detectable difference.

Construct validity of the 6MPT

There was a significant and strong correlation between the 6MPT and the 1SPT results (r=0.73 [95% CI 0.601–0.822]; p<0.001), and a significant but small correlation between the 6MPT result and HR_{6MPT} (r=0.29 [95% CI 0.064–0.488]; p=0.014). At the end of the 6MPT, the heart rate of participants varied between 72 and 199 beats per minute (bpm; mean HR_{6MPT} 138.5bpm; SD 26.5bpm).

DISCUSSION

The purpose of this study was to determine the two aspects of reproducibility (reliability and agreement) of both the 6MPT and 1SPT in children and adolescents with CP who self-propel a manual wheelchair. Reliability of both measurements can be considered excellent, with ICCs of 0.97 (with 95% CI 0.96–0.98). These ICCs are similar to those reported on the 6MWT in the literature, ranging from 0.96 to 0.98 in children with and without a chronic disease.[16,17]

For clinicians looking for meaningful improvements in a single patient, agreement of the measurements is more of interest. A high correlation does not automatically imply that there is good agreement. Agreement in 6MWT performance varies among paediatric populations, with SDDs ranging from 36m in children with spina bifida[16] up to 139m in children with cystic fibrosis.[17] In this study, the SDD for the 6MPT was 57.9m. To determine the range in which a person's 'true score' could be expected to lie, the calculated SDD can be used. For example, we can be 95% confident that total increases of 57.9m in the 6MPT and 1.4m for the 1SPT could be ascribed to a real change.

The limits of agreement for the 6MPT seem be relatively large for distances smaller than 200m (>30%) and, therefore, their value in the clinical evaluation of these children and adolescents with CP is questionable. Thus, although this measure has good reliability, the agreement statistics show that individual patients need to exhibit quite large changes in scores on the outcomes because of the large limits of agreement and SDDs, especially in the case of participants who achieve lower distances on the 6MPT.

Evaluation of construct validity requires that the correlations of the measure, in this case the 6MPT, be examined with regards to variables that are related to the construct. Since 6MPT distance is expected to be influenced by propulsion skill (measured using the 1SPT) and cardiovascular effort (measured with HR_{6MPT}), the significant and strong correlation between the 6MPT and the 1SPT supports the construct validity of the 6MPT. On the other hand, the correlation between the 6MPT and the HR_{6MPT} was small. Further study is required to investigate the construct validity of the 6MPT as an aerobic fitness test (e.g. comparing 6MPT distance with the peak oxygen uptake).

The skill required when performing the 6MPT (turning around the cone at the end of 10m) can be a specific skill that is not often required in the daily life of children with CP. Aspects related to spasticity, co-contraction, and poor motor control may reflect in mechanical inefficiency, which results in a low performance on the 6MPT and 1SPT. A post hoc analysis found a significant correlation between the 1SPT distance and the HR_{6MPT}. This indicates that children who have better propulsion skills can reach a higher heart rate during a submaximal exercise test. Therefore, performance in children classified as GMFCS levels II, III, and IV who have low propelling skills in a manual wheelchair, can be a reflection of their gross motor capacity rather than their submaximal fitness level.

As discussed by Verschuren et al.,[7] limitations of simply measuring the distance covered during a timed walk test include the lack of monitoring of physiological variables during the test and the absence of specific performance criteria to guarantee that a maximal effort is not performed. During the 6MPT, five children (four classified as GMFCS level III and one in GMFCS level IV) reached a HR_{6MPT} of 180 or higher. According to the physiological criteria established by Schulze-Neick et al.,[18] this indicates that these children reached a (near) maximal effort during the test. The HR_{6mpt} of 180bpm is 93% of the predicted peak heart rate for children with CP.[19] Thus, for some children, the 6MPT is a very intensive exercise test. In others, the 6MPT is hardly demanding, resulting in a HR_{6MPT} of less than 100bpm.

Field tests that rely on manual wheelchair propulsion performance are affected by many factors beyond motor limitations. Vanlandewijck et al.[20] have shown that the type of wheelchair (basketball/tennis wheelchair versus activities of daily living wheelchair) has an impact on field test performance. Minimal changes to wheelchair configuration, such as the presence or absence of a castor wheel, might significantly influence field test performance. Therefore, field tests such as the 6MPT and 1SPT for children and adolescents who self-propel a wheelchair should be used to measure individual progress. A standardized type of wheelchair should not be used, however, because it is not possible to adjust the wheelchair to the individual, and this would hamper performance.[21] The children who participated in this study used different types of wheelchair. Most children used bimanually driven non-powered wheelchairs (n=66). The other wheelchairs were single-side non-powered wheelchairs (n=3) and manual wheelchairs with electronic power (n=4). All children were included in the analysis, which improves the generalizability of results.

The probability of deterioration in gross motor function as a child grows is related to the degree of motor impairment, with children with a higher degree of impairment, such as those evaluated in this study (GMFCS levels II, III, IV), being more likely to deteriorate.[22] The functional tests described here can be used for longitudinal monitoring of motor function, providing the rehabilitation team with the relevant information required to propose strategies to improve performance. Moreover, these tests can be useful in programmes of physical activity and competitive sports plans.

Limitations

Certain limitations should be recognized when interpreting the results of this study. 6MPT results may be partially explained by unmeasured variables. For example, the motivation, mood, and compliance of individuals with CP when performing a submaximal exercise test can be questioned. We tried to account for certain behaviours by using standardized encouragement, according to the American Thoracic Society guidelines, during all tests. Furthermore, participants' physical activity and intellectual abilities were not directly measured. In this study, a 10m straight length was used. A circular course would probably result in less variability (i.e. with a straight course, those who need to use a wide turning circle would be scored as covering less distance). A heterogeneous group of 73 participants with CP completed the study, which is smaller than some samples used to measure the 6MWT's reliability in the general population. In addition, the age range of the sample crossed many phases of development, and this variability may have affected outcomes.

CONCLUSIONS

The 6MPT and 1SPT are easy to administer and inexpensive. Clinicians using both tests do not need special equipment or training, which makes the 6MPT and the 1SPT available for a variety of professionals working with children and adolescents with CP. However, reproducibility of the 6MPT and 1SPT for children with CP who self-propel a wheelchair should be considered carefully when these measures are used in the assessment or evaluation of this population. Agreement for the 6MPT seems be relatively large for children who achieve low distances and, therefore, its value in the clinical evaluation of these children and adolescents with CP is questionable. Construct validity is supported for the 6MPT in children with CP. Further study is required to investigate the construct validity of the 6MPT as an aerobic fitness test.

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